World Housing Encyclopedia Report

Country: Nepal

Housing Type: Uncoursed rubble stone masonry walls with timber floor and roof

Contributors:
Yogeshwar Krishna Parajuli
Jitendra Kumar Bothara
Bijay Kumar Upadhyay

Primary Reviewer:
Richard Sharpe

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1 General Information

1.1 Country
Nepal

1.3 Housing Type
Uncoursed rubble stone masonry walls with timber floor and roof

1.4 Summary
This is a typical rural housing construction spread in Nepal from east to west throughout the hills and mountains. It is a traditional construction practice followed for over 200 years. These buildings are basically loose fit loadbearing structures constructed of uncoursed rubble stone walls in mud mortar and timber floors and roof. These buildings are expected to be extremely vulnerable to earthquake effects due to the lack of integrity.

FIGURE 1: Typical Building

1.5 Typical Period of Practice for Buildings of This Construction Type

How long has this construction been practiced	
< 25 years	
< 50 years	
< 75 years	
< 100 years	
< 200 years	
> 200 years	X

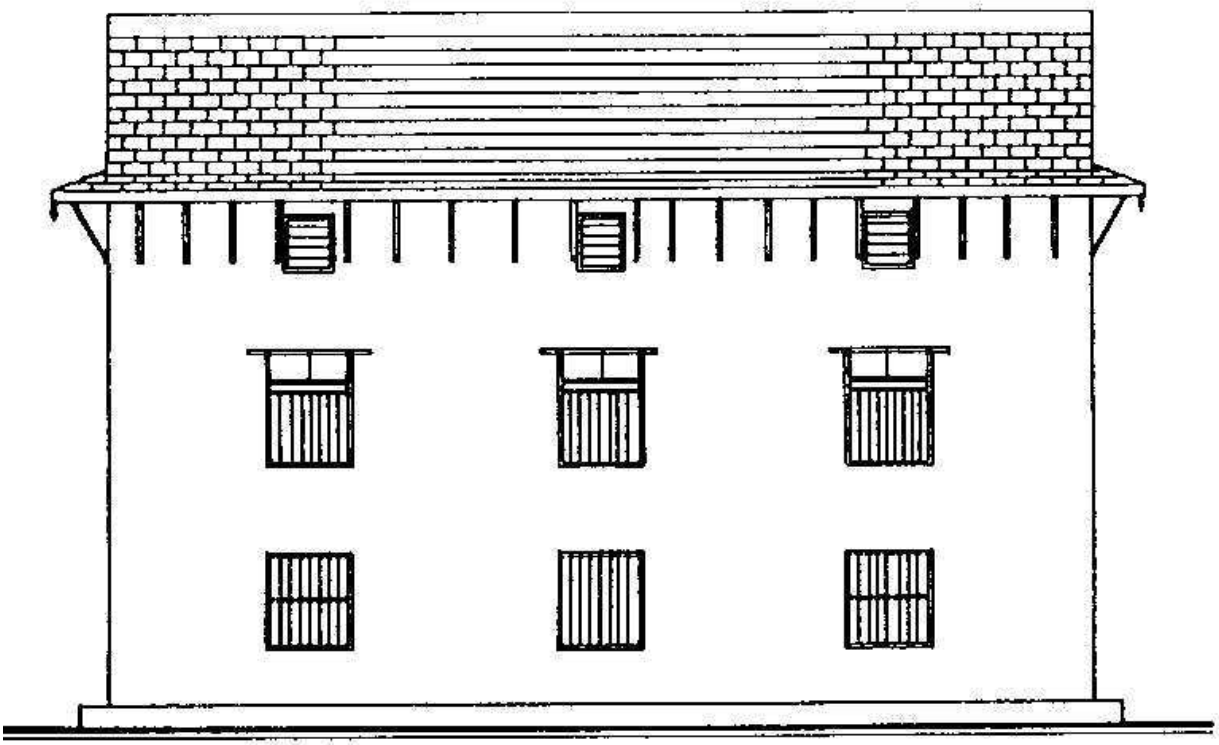
Is this construction still being practiced?	Yes	No
	X	

Additional Comments: Traditional construction being followed for over 200 years.

1.6 Region(s) Where Used
It is a traditional housing most extensively constructed throughout the foothills, hills and mountains of Nepal. Participation of this building type in total stock as well as total population inhibiting this building type is unknown.

1.7 Urban vs. Rural Construction

Where is this construction commonly found?	
In urban areas	
In rural areas	
In suburban areas	
Both in rural and urban areas	X



NORTH ELEVATION

FIGURE 2: Key Load-Bearing Elements

2 Architectural Features

2.1 Openings

Typically three to four openings are provided in each story, one for door and rest for windows in main building. Front façade has more openings than the back. Openings are limited in size. Openings constitute some 15-20% or even less of total wall length. Spacing between openings is generally more than twice the length of opening.

2.2 Siting

	Yes	No
Is this type of construction typically found on flat terrain?	X	
Is this type of construction typically found on sloped terrain? (hilly areas)	X	
Is it typical for buildings of this type to have common walls with adjacent buildings?		X

The typical separation distance between buildings is meters

2.3 Building Configuration

Building plan is rectangular in shape.

2.4 Building Function

What is the main function for buildings of this type?	
Single family house	X
Multiple housing units	
Mixed use (commercial ground floor, residential above)	X
Other (explain below)	

2.5 Means of Escape

There is usually only one door in a building of this type.

2.6 Modification of Buildings

3 Socio-Economic Issues

3.1 Patterns of Occupancy

Single or multy-family housing.

3.2 Number of Housing Units in a Building

1 units in each building.

3.3 Average Number of Inhabitants in a Building

How many inhabitants reside in a typical building of this construction type?	During the day / business hours	During the evening / night
< 5		
5 to 10	X	X
10-20		
> 20		
Other		

3.4 Number of Bathrooms or Latrines per Housing Unit

Number of Bathrooms: 0
Number of Latrines: 0

Additional Comments: This building typology does not comprise attached toilet or bathroom. In the past, there were no latrines or bathrooms available in this type of houses. Presently, toilets are constructed but away from the houses and in isolation.

3.5 Economic Level of Inhabitants

Economic Status		House Price/Annual Income (Ratio)
Very poor		/
Poor	X	/
Middle Class	X	/
Rich	X	/

Additional Comments: It is hard to establish house price/annual income ratio due to the informal housing construction.

3.6 Typical Sources of Financing

What is the typical source of financing for buildings of this type?	
Owner Financed	X
Personal Savings	X
Informal Network: friends and relatives	X
Small lending institutions/microfinance institutions	
Commercial banks / mortages	
Investment pools	
Combination (explain)	
Government-owned housing	
Other	

3.7 Ownership

Type of Ownership/Occupancy	
Rent	
Own outright	X
Own with Debt (mortgage or other)	
Units owned individually (condominium)	
Owned by group or pool	
Long-term lease	
Other	

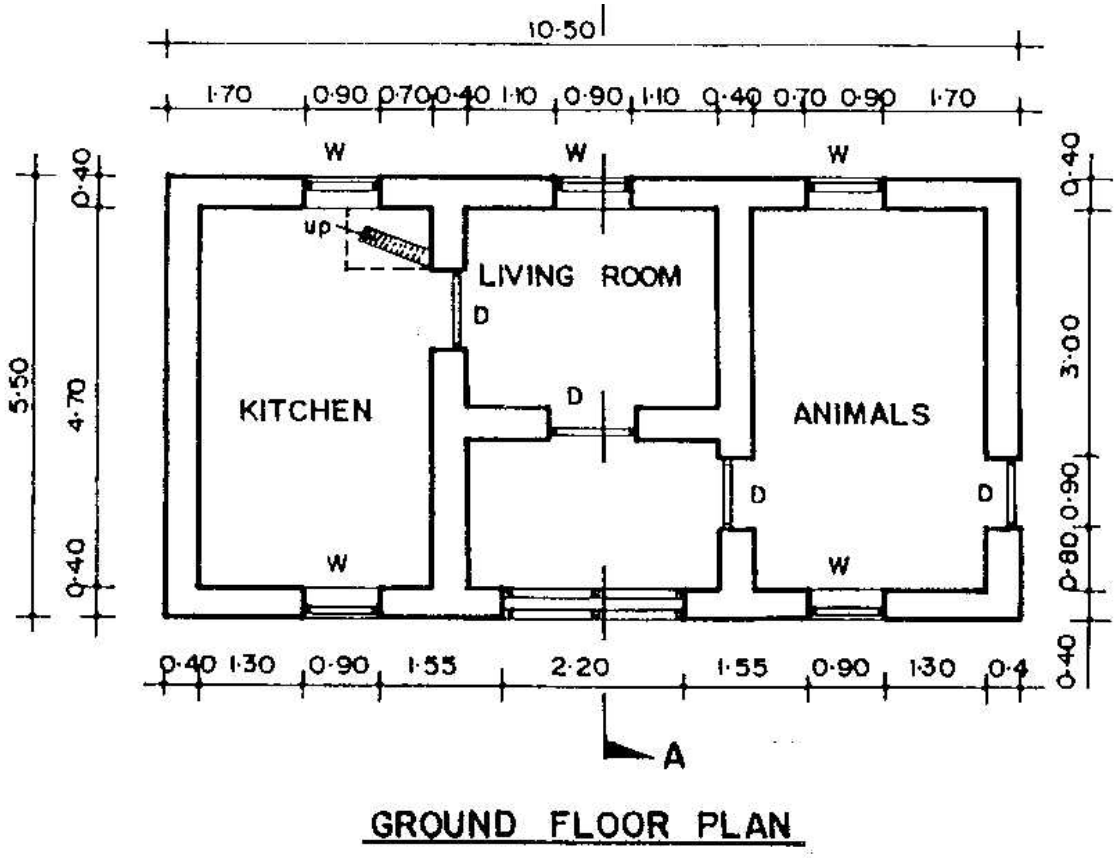


FIGURE 3: Ground Floor Plan

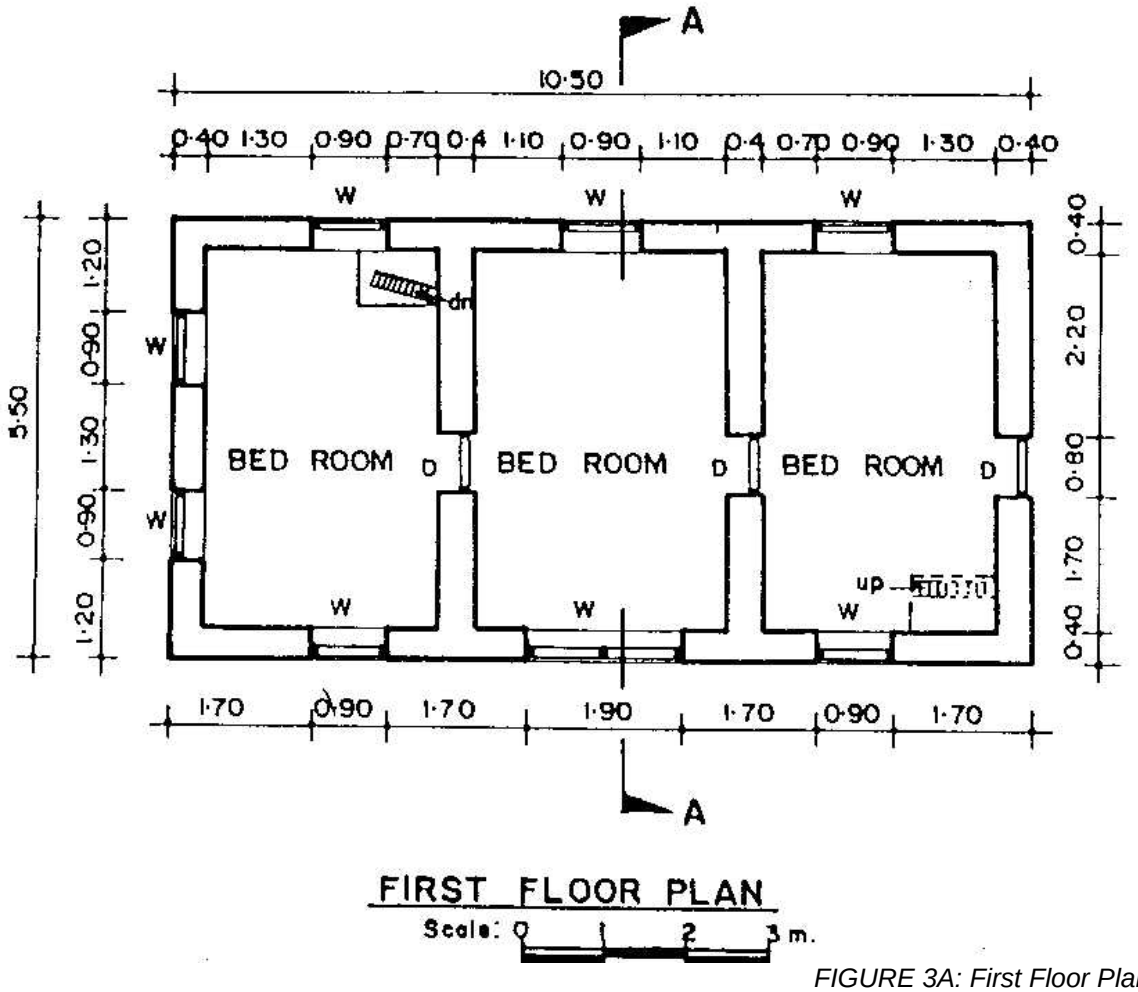
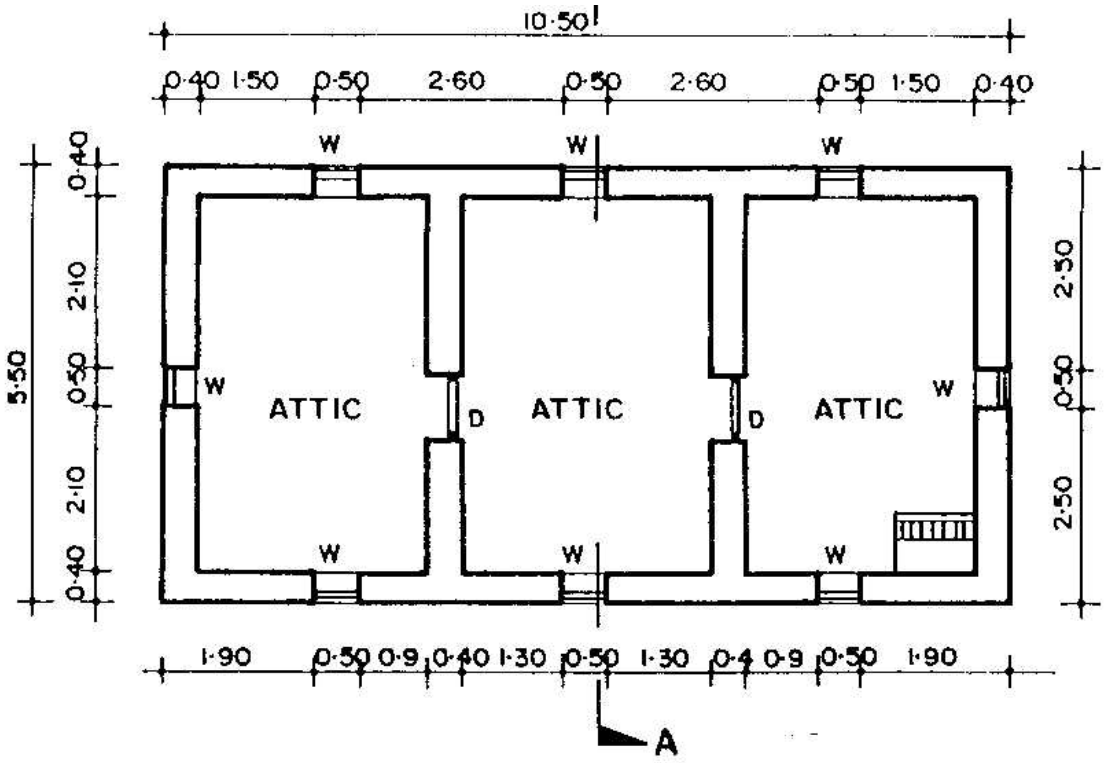
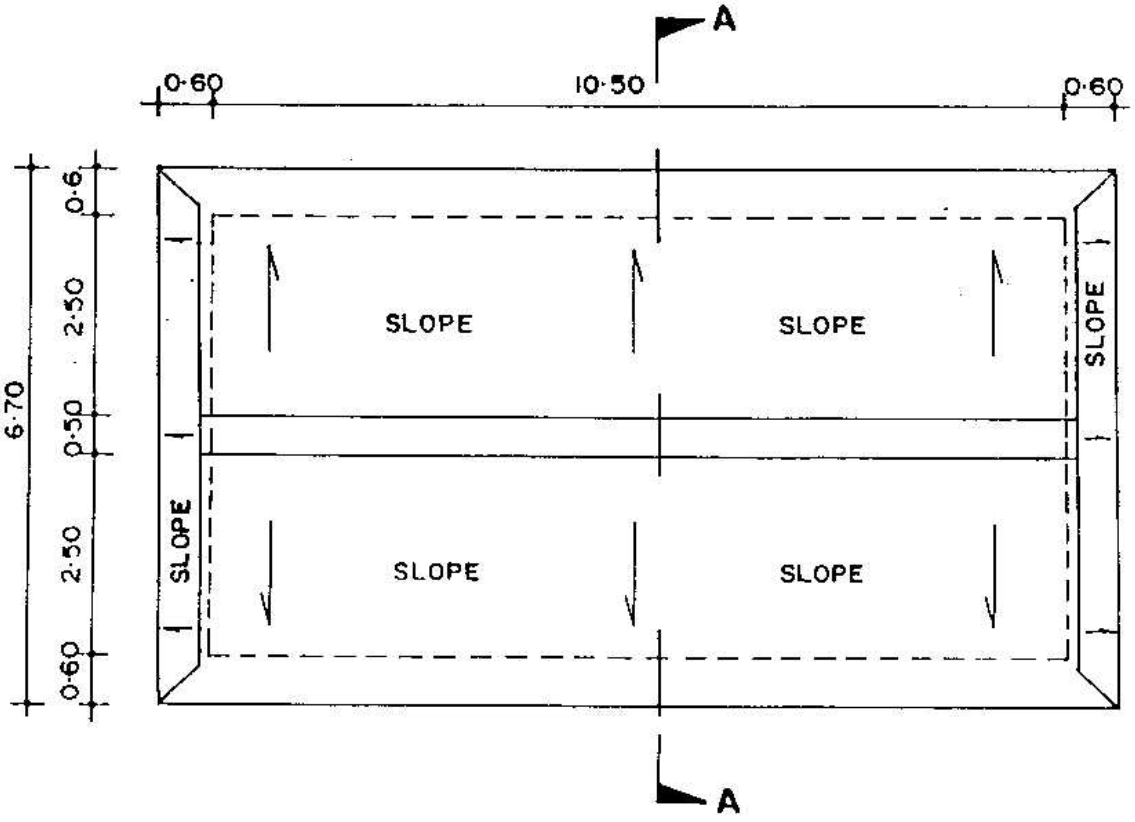


FIGURE 3A: First Floor Plan



SECOND FLOOR PLAN

FIGURE 3B: Second Floor Plan



ROOF PLAN

FIGURE 3C: Roof Plan

4 Structural Features

4.1 Lateral Load-Resisting System

The loadbearing masonry walls carry the lateral load i.e. masonry walls act as shear walls.

4.2 Gravity Load-Bearing Structure

The gravity loads of main building are carried by loadbearing stone masonry walls (typical thickness 450 to 600 mm). Floor and roof are timber structures, which transfer the load to the walls down to the foundation (uncoursed rubble stone masonry strip footings).
The verandah (annex to the main building), a lean-to structure to main building, is supported by timber posts. The posts generally rest above ground on stone pedestals without any anchorage. Beam-column connections at the verandah are not rigid.

4.3 Type of Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	
Masonry	Stone masonry walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	X
		2	Massive stone masonry (in lime or cement mortar)	X
	Earthen walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block or brick walls	
		6	Rammed earth/Pise construction	
	Unreinforced brick masonry walls	7	Unreinforced brick masonry in mud or lime mortar	
		8	Unreinforced brick masonry in mud or lime mortar with vertical posts	
		9	Unreinforced brick masonry in cement or lime mortar (various floor/roof systems)	
	Confined masonry	10	Confined brick/block masonry with concrete posts/tie columns and beams	
	Concrete block masonry walls	11	Unreinforced in lime or cement mortar (various floor/roof systems)	
		12	Reinforced in cement mortar (various floor/roof systems)	
		13	Large concrete block walls with concrete floors and roofs	
Concrete	Moment resisting frame	14	Designed for gravity loads only (predating seismic codes i.e. no seismic features)	
		15	Designed with seismic features (various ages)	
		16	Frame with unreinforced masonry infill walls	
		17	Flat slab structure	
		18	Precast frame structure	
		19	Frame with concrete shear walls-dual system	
		20	Precast prestressed frame with shear walls	
	Shear wall structure	21	Walls cast in-situ	
		22	Precast wall panel structure	
Steel	Moment resisting frame	23	With brick masonry partitions	
		24	With cast in-situ concrete walls	
		25	With lightweight partitions	
	Braced frame	26	Concentric	
		27	Eccentric	
Timber	Load-bearing timber frame	28	Thatch	
		29	Post and beam frame	
		30	Walls with bamboo/reed mesh and post (wattle and daub)	
		31	Wooden frame (with or without infill)	
		32	Stud wall frame with plywood/gypsum board sheathing	
		33	Wooden panel or log construction	
Various	Seismic protection systems	34	Building protected with base isolation devices or seismic dampers	
	Other	35		

4.4 Type of Foundation

Type	Description	
Shallow Foundation	Wall or column embedded in soil, without footing	
	Rubble stone (fieldstone) isolated footing	
	Rubble stone (fieldstone) strip footing	X
	Reinforced concrete isolated footing	
	Reinforced concrete strip footing	
	Mat foundation	
	No foundation	
Deep Foundation	Reinforced concrete bearing piles	
	Reinforced concrete skin friction piles	
	Steel bearing piles	
	Wood piles	
	Steel skin friction piles	
	Cast in place concrete piers	
	Caissons	
Other		

4.5 Type of Floor/Roof System

Material	Description of floor/roof system	Floor	Roof
Masonry	Vaulted		
	Composite masonry and concrete joist		
Structural Concrete	Solid slabs (cast in place or precast)		
	Cast in place waffle slabs		
	Cast in place flat slabs		
	Precast joist system		
	Precast hollow core slabs		
	Precast beams with concrete topping		
	Post-tensioned slabs		
Steel	Composite steel deck with concrete slab		
Timber	Rammed earth with ballast and concrete or plaster finishing		
	Wood planks or beams with ballast and concrete or plaster finishing		
	Thatched roof supported on wood purlins		X
	Wood single roof		X
	Wood planks or beams that support clay tiles		
	Wood planks or beams that support slate, metal asbestos-cement or plastic corrugated sheets or tiles		X
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls		
Timber	Wood planks (or fire wood) and joists covered with thick mud overlay	X	

Additional Comments: Floor and roof structures are loose fit structure, with one component stacked atop the other without any nailing, and should be considered as a flexible diaphragm. In past earthquakes such floors were scattered due to ground shaking.

4.6 Typical Plan Dimensions

Length: 6 - 10 meters
Width: 6 - 10 meters
Additional Comments: Length varies from 6 to 10.0 m, and the width varies from 4-7 m.

4.7 Typical Number of Stories

2

4.8 Typical Story Height

2.2 meters

4.9 Typical Span

5 meters

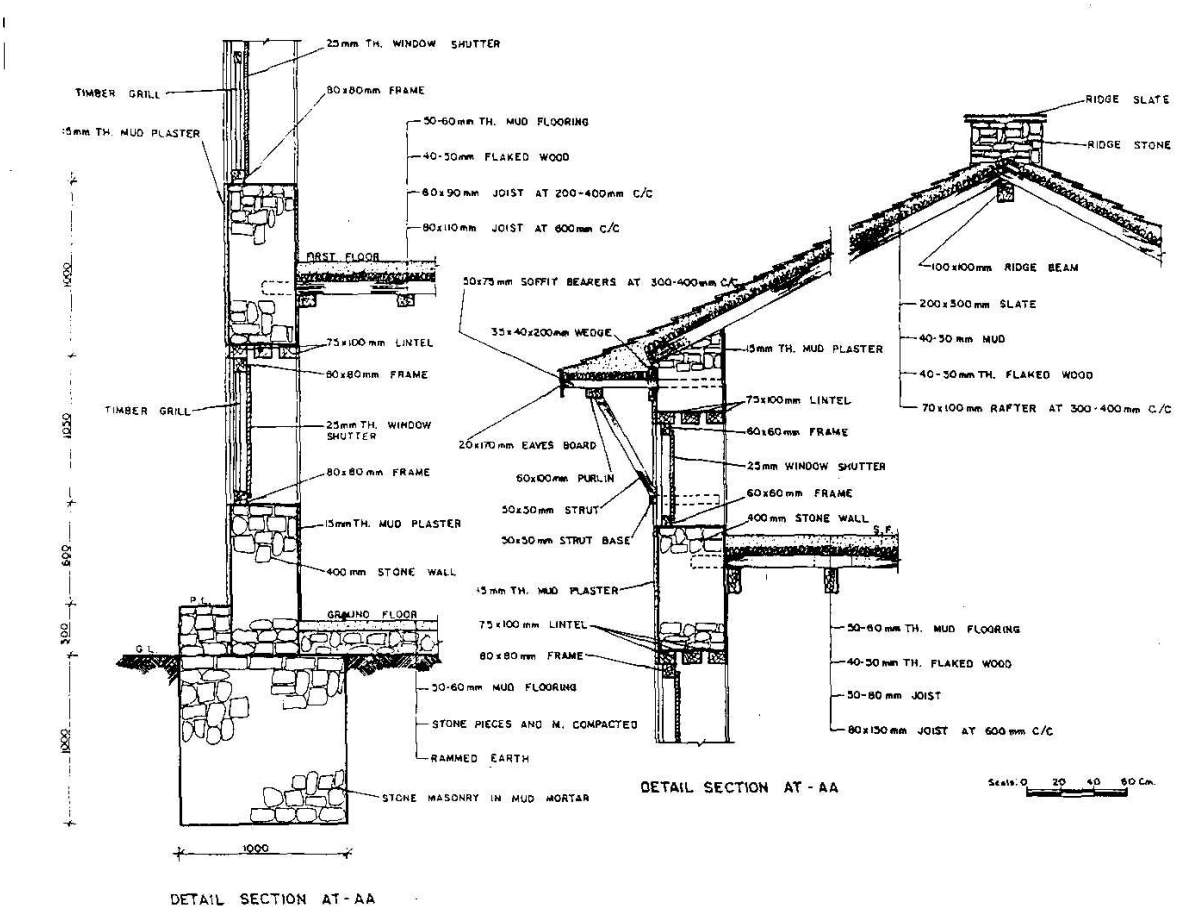
Additional Comments: ypical distance between the cross wall varies from 4-6m

4.10 Typical Wall Density

25% - 25%
Total wall density (total plan area of wall/ total plinth area) is around 25%.

4.11 General Applicability of Answers to Questions in Section 4

This contribution describes a generic construction type, and not only a single building.



DETAIL SECTION AT - AA

FIGURE 4: Critical Structural Details - Wall Section, Foundations, Roof-Wall Connections

5 Evaluation of Seismic Performance and Seismic Vulnerability

5.1 Structural and Architectural Features: Seismic Resistance

Structural/ Architectural Feature	Statement	True	False	N/A
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces form the building to the foundation.	X		
Building configuration	The building is regular with regards to both the plan and the elevation.	X		
Roof construction	The roof diaphragm is considered to be rigid and it is expected that the roof structure will maintain its integrity, i.e.. shape and form, during an earthquake of intensity expected in this area.		X	
Floor construction	The floor diaphragm(s) are considered to be rigid and it is expected that the floor structure(s) will maintain its integrity, during an earthquake of intensity expected in this area.		X	
Foundation performance	There is no evidence of excessive foundation movement (e.g. settlement) that would affect the integrity or performance of the structure in an earthquake.	X		
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	X		
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: 1) Less than 25 (concrete walls); 2)Less than 30 (reinforced masonry walls); 3) Less than 13 (unreinforced masonry walls).	X		
Foundation- wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.		X	
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.		X	
Wall openings	The total width of door and window openings in a wall is: 1) for brick masonry construction in cement mortar: less than 1/2 of the distance between the adjacent cross walls; 2) for adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; 3) for precast concrete wall structures: less than 3/4 of the length of a perimeter wall.	X		
Quality of building materials	Quality of building materials is considered to be adequate per requirements of national codes and standards (an estimate).			
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).		X	
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	X		
Other				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake-Resilient Features	Earthquake Damage Patterns
Wall	-Binding material (mortar) for walling is too weak (mud mortar) or there is no binding material at all (dry stone masonry). -Stone units (boulders) are irregular; -Absence of header stones at wall junctions and corners. -Absence of through stones.	In some cases, bond stones or timber bands are provided.	-Separation of the walls at the junctions, in-plane and out-of-plane wall failure.
Timber Frame (verandah)	-Inadequate beam-column and beam-wall connections. -Lack of anchorage between timber posts and foundation.		
Roof and floors	-Flexible -Lack of integrity (connections) between different structural elements -Absence of wall-floor and wall-roof connection (in general) -Heavy floors		-Total disintegration of roof/ floor structure, separation of floor/ roof structure from walls due to the absence of wall-floor anchorage (ties).
Foundation	- Inadequate foundation provided		-As the superstructure is very weak, superstructure fails before the foundation.

5.3 Seismic Vulnerability Rating

	Vulnerability					
	High (Very Poor Seismic Performance) A	B	Medium C	D	E	Low (Excellent Seismic Performace) F
Seismic Vulnerability Class	0	>				

0 - probable value
< - lower bound
> - upper bound

FIGURE 5: Key Seismic Deficiencies-Lack of Connection Between the Wall Wythes (note loose stone rubble)

FIGURE 5A: Seismic Deficiencies - Inadequate Wall-Roof Connections

6 Earthquake Damage Patterns

6.1 Past Earthquakes Reported To Affect This Construction

Year	Earthquake Epicenter	Richter magnitude(M)	Maximum Intensity (Indicate Scale e.g. MMI, MSK)
1988	Udaypur Eartquake	6.4	VIII
1999	Chamoli, India	6.5	VIII

Additional Comments: This building type is among the most vulnerable to earthquake effects, as it suffers fatal damage in even minor shaking. Many building in Nepal suffered severe damage in the 1999 Chamoli Eartquake, although the epicentre was approximately 140 km away. The main source of damage is loss of integrity of building components, dislodging of rubble stones, delamination of walls etc. skata

FIGURE 6: Typical Earthquake Damage-Roof Collapse Due to the Absence of Wall-Roof Connection

FIGURE 6A: Typical Earthquake Damage - Delamination of Stone Walls due to Absence of Bond Stones (through-stones)

FIGURE 6B: Typical Earthquake Damage to Stone Masonry Buildings

FIGURE 6C: Complete Collapse of a Stone Building in an Earthquake

FIGURE 6D: Typical Earthquake Damage -Out-of-plane Wall Collapse Due to Lack of Anchorage

FIGURE 6E: Typical Earthquake Damage -Wall Bulging due to Delamination

FIGURE 6F: Typical Earthquake Damage - In-plane Failure of a Stone Masonry Wall

7 Building Materials and Construction Process

7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Walls	Rubble stone	Not known	Irregular boulders (size 200-300mm or less)	Slates, lime stone, quartzite
Foundations	Mud	Very low compressive strength and no tensile strength		Used for mortar
Timber Frame	Soft wood and hard wood		Depending on structural value of the member	Hard wood used for main structural elements (e.g. columns, main beams), whereas softwood was used for structural members of secondary importance (eg. joists, purlins)
Roof and floors	Timber/ bamboo	Not known		Difficult to define because of use of various wood species
Roofing material	Thatch, shingle, slate, corrugated iron sheets			The choce of roofing material depends on availability of materials and cost

7.2 Does the builder typically live in this construction type, or is it more typically built by developers or for speculation?

Yes, builders/owners live in this construction type (house-owner himself is a part of the construction team).

7.3 Construction Process

The walls are constructed in a random uncoursed manner by using irregular stones bound with mud mortar. The stones are collected from quarries, riverbed or field, sometimes partially dressed. Space between interior and exterior wythes is filled with stone rubble and mud. The joists and rafters are placed on walls without any anchorage or connection. This type of buildings are owner-built where village artisans play pivotal role.
Simple tools such as chisels, hammers, saw etc are used for construction.

7.4 Design/Construction Expertise

The artisans do not have any formal training. The construction know-how is transferred from generation to generation or the people learn the process on site in very informal way. The head mason is skilled but the level of know-how varies from person to person. There are no standard or minimum qualification requirements for head mason or other masons. Besides the head mason, the working team is composed of semi-skilled or unskilled personnel.

7.5 Building Codes and Standards

	Yes	No
Is this construction type addressed by codes/standards?	X	

Title of the code or standard: NBC203 : Guidelines for Earthquake Resistant Building Construction: Low Strength Masonry (Draft)

7.6 Role of Engineers and Architects

Engineers, architects and technicians are not involved in this construction type unless these are constructed by government agency.

7.7 Building Permits and Development Control Rules

	Yes	No
Building permits are required		X
Informal construction	X	
Construction authorized per development control rules		X

Additional Comments: The building bylaws, building permit process and building construction controlling monitoring mechanisms only exists in municipality areas and not in Village Development Committee (local authority at village units-rural areas). This type is basically a rural house type where building permit process does not exist. If this building type is constructed in a municipality area, it has to follow the formal process, however the approval of structural drawings for a building of this size is not required. Present building bylaws or regulations do not prohibit the construction of this type of building in municipal areas.

7.8 Phasing of Construction

	Yes	No
Construction takes place over time (incrementally)	X	
Building originally designed for its final constructed size		X

7.9 Building Maintenance

Who typically maintains buildings of this type?	
Builder	
Owner(s)	X
Renter(s)	
No one	
Other	

7.10 Process for Building Code Enforcement

Process for building code enforcement in rural areas (Village Development Committee areas) does not exist.

7.11 Typical Problems Associated with this Type of Construction

Weak construction materials/ and construction technology, lack of quality control, lack of earthquake-resistant features are the problems associated with this type of construction.

FIGURE 7: Illustration of Seismic Strengthening Techniques

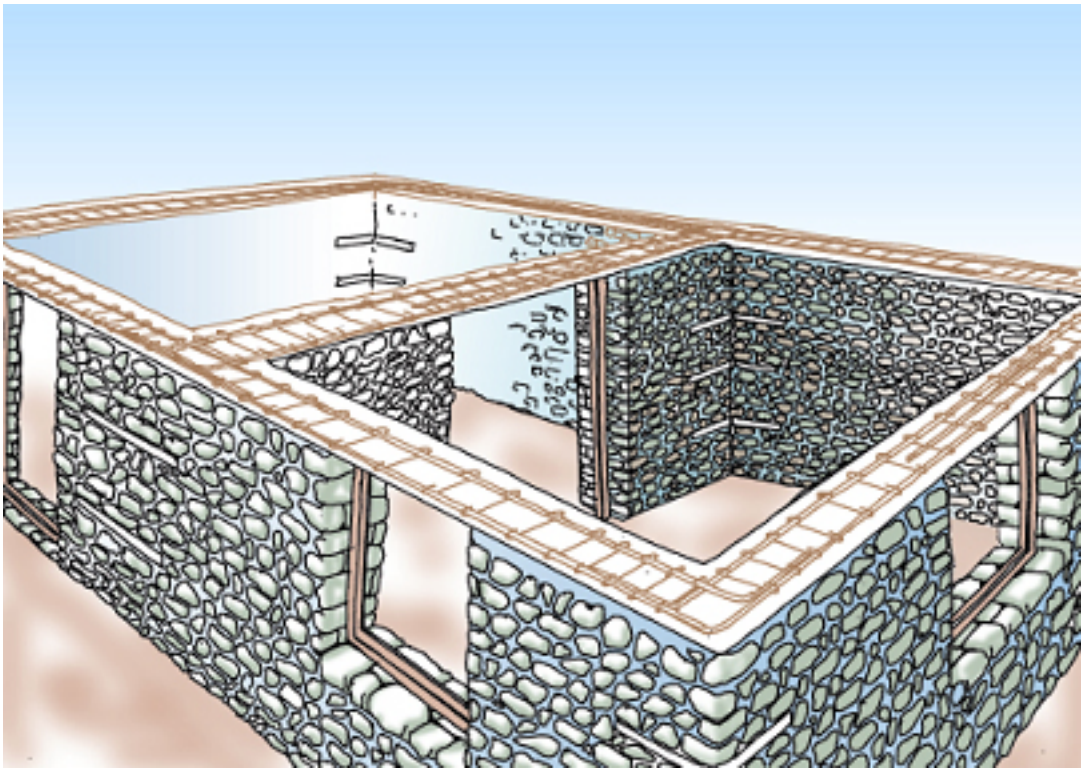


FIGURE 7A: Seismic Strengthening Techniques-Stone Masonry Walls Strengthened with Wall Corner Stitches and Bands (bond beams)

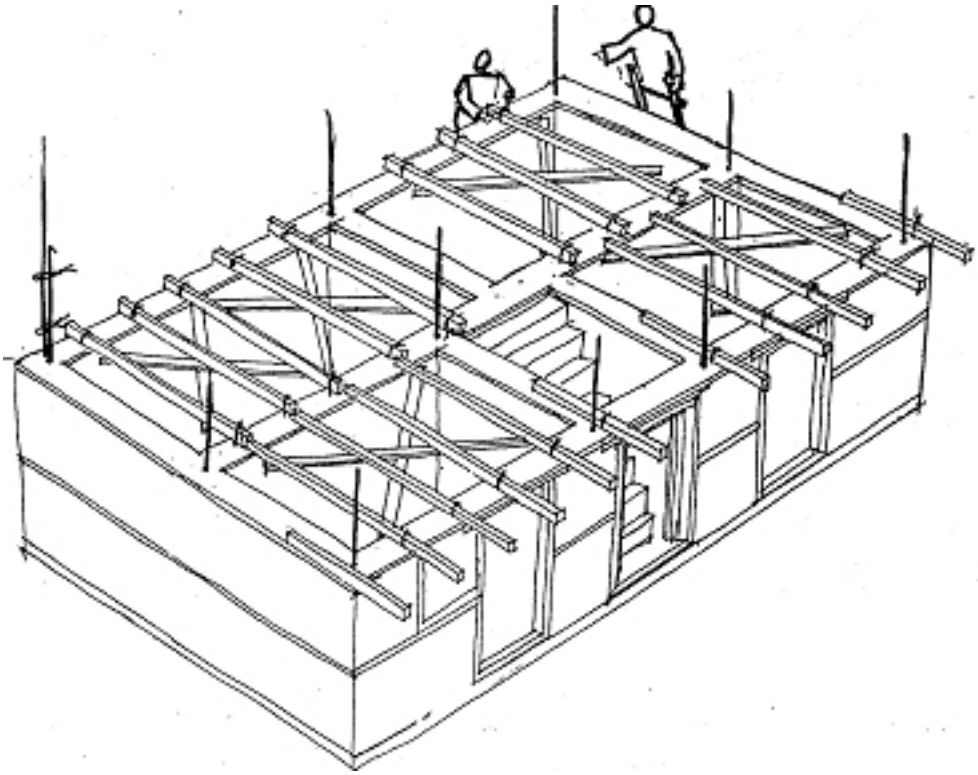


FIGURE 7B: Seismic Strengthening - Floor Horizonntal Bracing and Vertical Reinforcement Bars

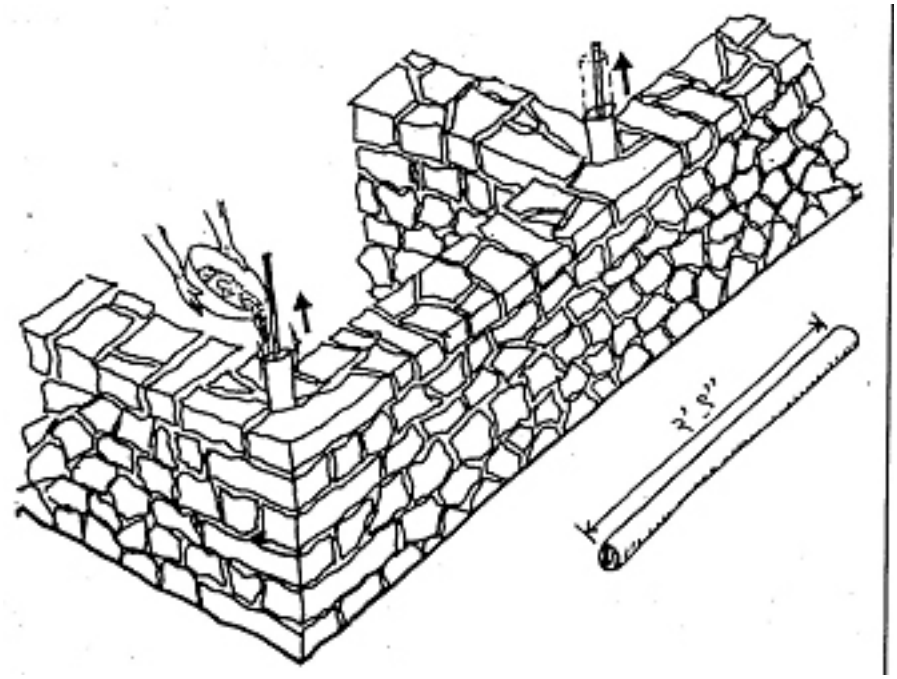


FIGURE 7C: Seismic Strengthening - Installation of Vertical Bars at Wall Corners

8 Construction Economics

8.1 Unit Construction Cost (estimate)

Cash flow in such construction is very minimal so it is difficult to price the building cost.

8.2 Labor Requirements (estimate)

120 # 150 man-days (excluding effort required for collection of construction materials).

9 Insurance

9.1 Insurance Issues

	Yes	No
Earthquake insurance for this construction type is typically available		X
Insurance premium discounts or higher coverages are available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features		X

9.2 If earthquake insurance is available, what does this insurance typically cover/cost?

Not applicable.

10 Seismic Strengthening Technologies

10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used
Retrofit (Strengthening)	Delamination of walls	Introduction of bond (through) stones
	Separation of walls at junctions	Introduction of stitches
	Out-of-plane collapse of walls	Introduction of bandage (reinforced concrete, timber, steel) at different levels, or bolting the oppostie walls
	Vertical tension (unstability)	Introduction of splints (reinforced concrete, steel, timber)
	Lack of integrity at floor/ roof leve	Nailing/ straping of different floor/ roof elements together and anchoring floor joists/ roof rafter with walls
	Floor/ roof flexibility	Introduction of floor/ roof bracing

10.2 Has seismic strengthening described in the above table been performed in design practice, and if so, to what extent?

The seismic strengthening described above will significantly increase seismic safety of the building to sustain an earthquake of moderate intensity. However, as the wall construction is rather weak, it is expected that even the strengthened buildings would not be able to sustain a major earthquake.

10.3 Was the work done as a mitigation effort on an undamaged building, or as repair following earthquake damage?

10.4 Was the construction inspected in the same manner as new construction?

Not very often.

10.5 Who performed the construction: a contractor, or owner/user? Was an architect or engineer involved?

These are mostly owner-built buildings. Sometimes engineers/architects are involved, if the construction is formal (government-funded or if funding is provided by international organizations) and if constructed in remote areas.

10.6 What has been the performance of retrofitted buildings of this type in subsequent earthquakes?

There were no reported major earthquakes after the construction was performed.

11 References

1. _____, 1994, Appendix-A: Prototype Building inventory; the Development of Alternative Building Materials and Technologies for Nepal, UNDP/UNCHS (Habitat) Sub-project Nep 88/054/21.03, His Majesty's Government of Nepal, Ministry of House and Physical Planning.

2. _____, 1994, NBC 203 Guidelines for Earthquake Resistant Building Construction: Low Strength Masonry, UNDP/UNCHS (Habitat) Sub-project Nep 88/054/21.03, His Majesty's Government of Nepal, Ministry of House and Physical Planning.

12 Contributors

Name	Yogeshwar Krishna Parajuli	Jitendra Kumar Bothara	Bijay Kumar Upadhyay
Title	Architect	Structural Engineer	Building Technologist
Affiliation	National Team Leader, Nepal National Building Code Development Project; C/O TAEC Consult P. Ltd.	Team Member, Nepal National Building Code Development Project; C/O TAEC Consult P. Ltd.	Team Member, Nepal National Building Code Development Project; C/O TAEC Consult P. Ltd.
Address	Shankhamul		Shankhamul
City	Kathmandu	Shankhamul, Kathmandu	Kathmandu
Zipcode			
Country	Nepal	Nepal	Nepal
Phone	+977-1-498446	+977-1-498446	+977-1-417471
Fax	+977-1-498447	+977-1-498447	
Email	taec@mos.com.np	taec@mos.com.np	taec@mos.com.np
Webpage			

13 Figures

FIGURE 1: Typical Building